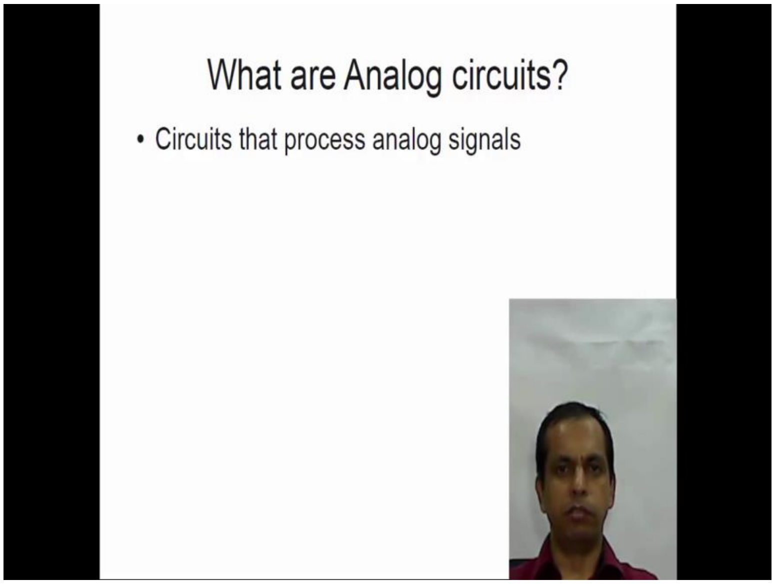
Analog Circuits
Prof. Nagendra Krishnapura
Department of Electrical Engineering
Indian Institute of Technology, Madras

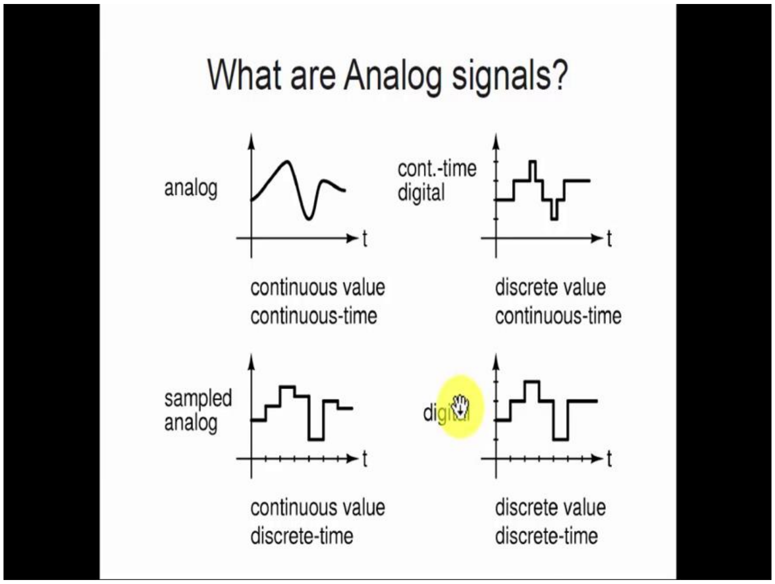
Module - 01
Lecture – 01

(Refer Slide Time: 00:12)



Hello everyone, welcome to the online course Analog Circuits. I am Nagendra Krishnapura, I am from the department of electrical engineering at IIT, Madras. This is an introduction to the course, first we will go through what analog circuits are then see what the contents of the course will be and go through what we go to achieve by learning this course. First of all, what are analog circuits, now put very simply there are circuits that process analog signals. Now many of you may be familiar with different types of signals.

(Refer Slide Time: 00:37)

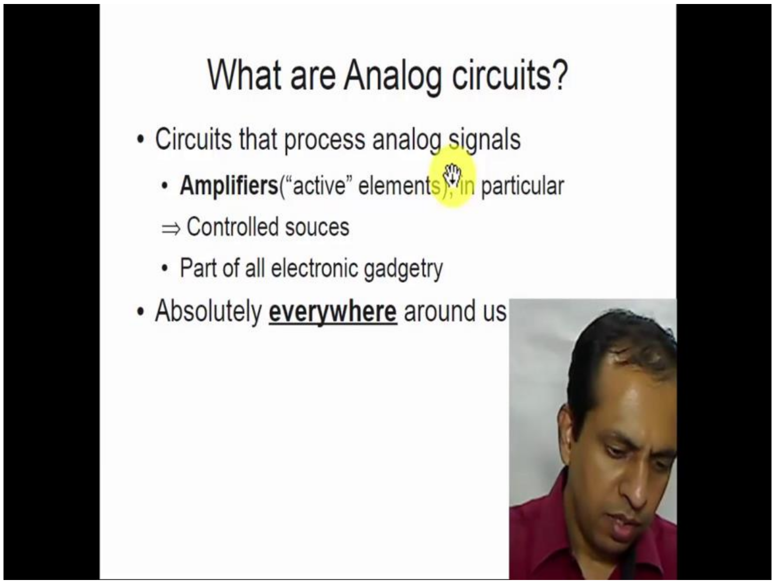


They are shown here; at the top left, I have shown something as labeled as analog. And here if you observe, there is some signals that is varying with time and the points are defined for every value of time that is it's continuous in time and also the values can be anything along the y axis, so it is continuous in amplitude. So if it is continuous valued or continuous in amplitude and it is defined for continuous time then it is an analog signals; more specifically it's a continuous time analog signals. Now what are the other types of signals, it is possible that the signal is defined or signal changes only at discrete instants of time. The discreteness of the time axis is marked here, this is the bottom left picture, so this tick marks denote instant at which the signal can change. You see that it changes only at discrete instant of time but the values along the y axis can be anything and such a signal is known as a discrete time continuous valued signal or a sample data analog signal.

And you can have the counter part where the signal can vary at any instant of time this is shown on the top right which have labeled as continuous time digital. So the signal can vary at any instant of time so the x-axis is the continuous but it can only take on certain discrete values along the y axis. So this is the continuous time digital signal and this is not very often seen but it is very much possible to have this. Finally, you could have discretization along both x and y axis that is the signal changes only at discrete instant of time that also will take on only discrete values, this is known as a discrete time discrete valued signal or more commonly as a digital signal. And you would be familiar with the particular variant of it, where there are only two possible values along the y axis that is a binary digital signal but that's what we would normally call a digital signal. So this is an analog signal and this is the digital signal. And analog circuits are circuits that process analog signals, now that is one definition of it but that definition is almost completely useless for you to understand what we will be talking about in this course, because there is the variety of circuits that process signals like this which we won't be talking about at all, which we have learned in a previous course.

For instance, if you have circuits that are made of resistors, capacitors and inductors they will of course process signals like this. Signals that are defined for every instant of time and can take on any value. And the output of those circuits let say RC circuits or RLC circuits or just purely resistor circuit will also be continuous valued and will be defined for continuous time if the input is continuous time, so that definition is useless.

(Refer Slide Time: 03:36)

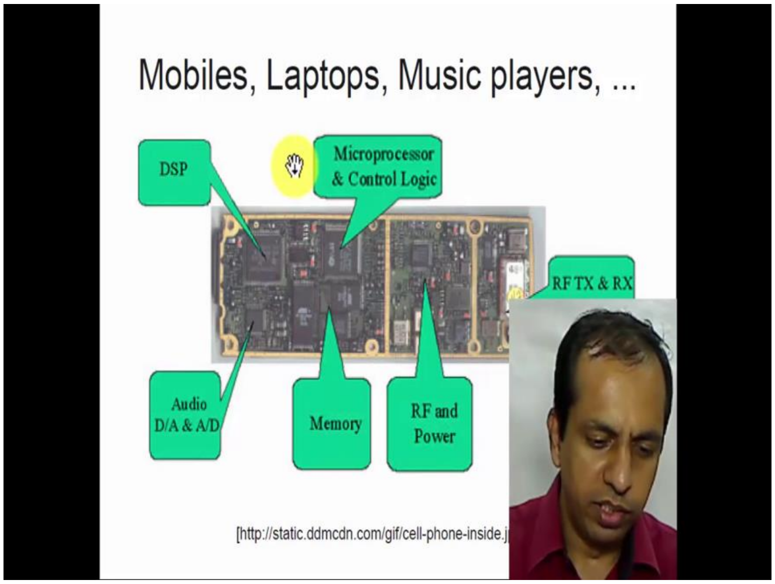


What we really mean by analog circuits, they do of course process analog signals. What we mean are really amplifiers that is active elements. So for all the elements that you have studied and circuits using those elements would have been passive. Now we will come across some elements which are active elements. Now we will look at the definition of this more carefully later, because as you know passive devices are devices which consume energy whereas active devices can generate energy. In reality, no physical device can generate energy by itself, it has to been provided from elsewhere; so there is a particular definition of active nature of circuits that we will see later, but clearly you would not have seen amplifier still now in your basic circuits' class and that is what we are going to study in this course. In particular, that means that these amplifiers are controlled sources. For instance, everyone would be familiar with an audio amplifier, so it takes the sound from the microphone, amplifies it that is makes the value larger and place it on an out speaker.

You can also think of that as some sort of a controlled source. Let say voltage control voltage source. It takes the voltage from the microphone and multiplies it by certain number k and gives you an output voltage which is dependent on the input voltage. So it is a dependent source or a controlled source. So these amplifiers are basically controlled sources. Now you would, of course, be familiar with those that is controlled sources and you would have seen them in your basic circuits' class but you do not know how to make them, how to construct them, because I have just taken as definitions that is some controlled sources given to you and they follow certain rules.

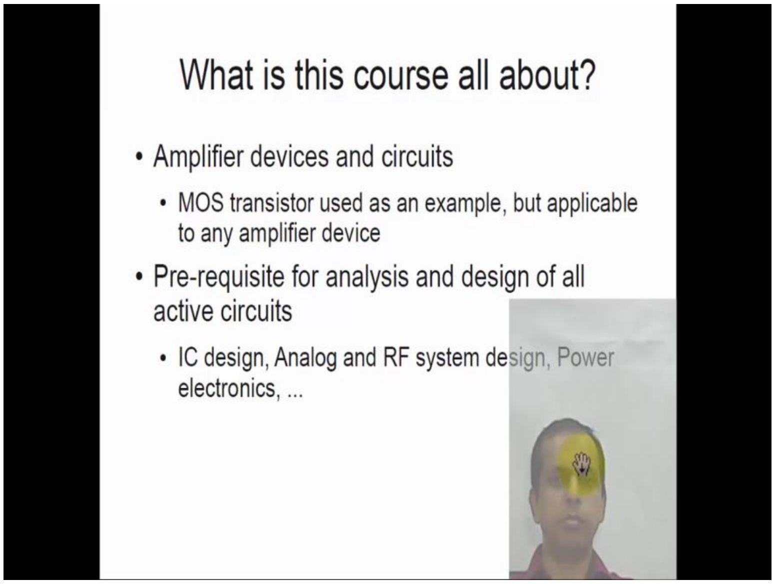
In this course, what we will do is to realize those controlled sources, and also understand their limitations. And these amplifiers are part of all electronic gadgetry, although I have started off saying they process analog circuits it turns out that amplifiers are also parts of digital circuits. Without amplifiers, you could not make any digital gate. And they are absolutely everywhere around us today we are surrounded by electronic gadgets, I am hooked on to this collar Mic here, it has an amplifier inside, I am using this and I am using the tablet PC, I am recording myself on a webcam so it's everywhere around me and around you as well, all of you will have mobile phones and all sorts of other electronic gadgets.

(Refer Slide Time: 06:11)



So just to show you an example, I have taken some picture from the web of a mobile phone and it has what are distinctly analog circuits such as audio, digital to analog and analog to digital converters, and RF amplifiers and so on, and RF and power circuits. Also like I said even in digital logic circuits, you need to have an amplifier. So even in memory and microprocessor and control logic and DSP, you will find analog circuits.

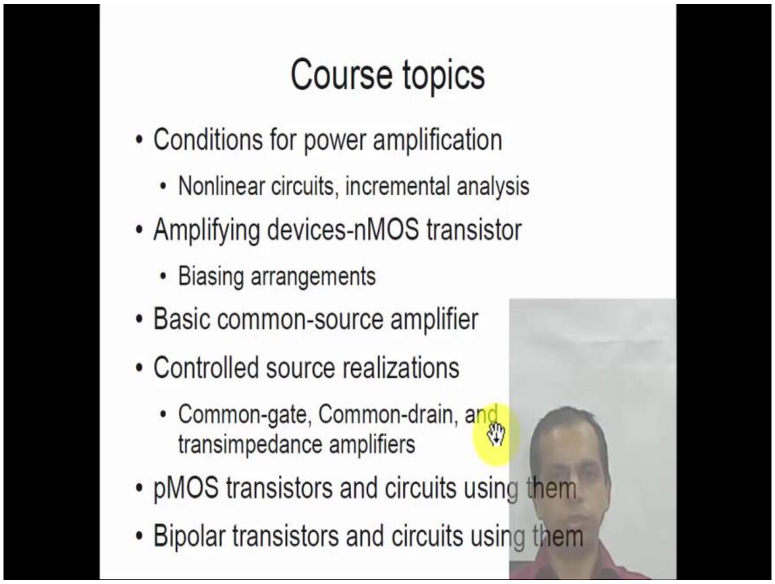
(Refer Slide Time: 06:40)



So what is this course all about then it’s about amplifier devices and circuits. Now in this course, we use MOS that is metal oxide semiconductor device as the amplifying device that is because MOS technology is the dominant technology of the day, but the principles that we learn in this course are useful even if the kind of device changes. Some of you may know a bit of history, first we started with vacuum tubes then we had bipolar junction transistors then MOS transistors that is also a number of other varieties of transistor and different process, the most predominant technology today is MOS technology in silicon. But you do not have to use silicon, and you do not have to use MOS, there is variety of other materials and other types of transistors. All of them once you understand the model can be understood analyzed and design using the principles you learn from this course. So tomorrow if someone invents a different technology, you have a different type of transistor or different type of amplifying device, you should still be able to analyze circuits using them and also design circuits using them.

Now, what could is this course, it turns out that this course is pre-requisite for analysis and design of all active circuits. So if you want to take up a job in IC design and do research in IC design or design any kind of analog and RF system or power electronics and so on, you need to be able to use the principles that you learn in this course.

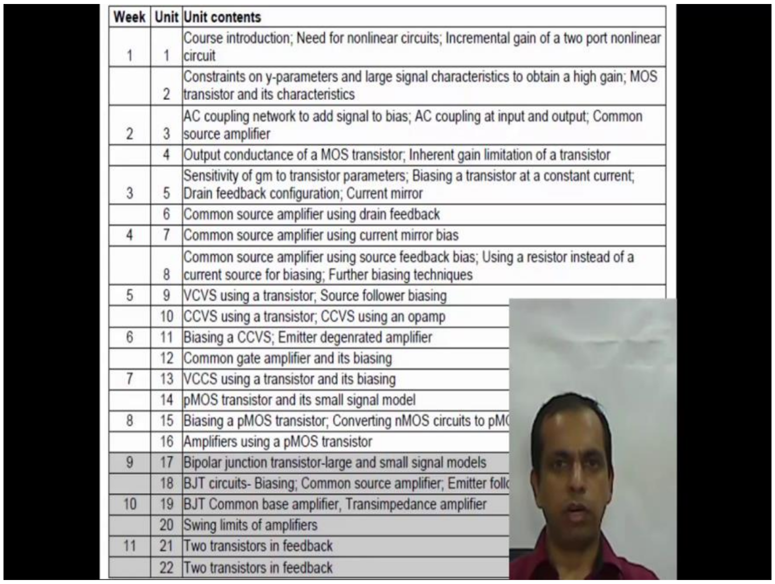
(Refer Slide Time: 08:11)



What are the course topics; first we will look at the need for non-linear elements. So far you would be familiar only with linear elements. Now, we will look at the need for non-linear elements and it is turns out the need is really amplification. I said that in this course we will mainly deal with amplifiers, and in order to make useful amplifiers, you need to have non-linear devices. You just can't make them with only linear devices. And we will look at one example of amplifying device which is known as the nMOS transistor and it turns out that, we have what are known as biasing arrangements that is we have to sort of certain operating voltage and current in the device and then on the top of that we have to apply the signal that we want to amplify.

So all these will become clear later in this course then we will come to the most basic form of amplifier which is known as a common-source amplifier. Then we look at controlled sources,it turns out that in order to realize this we have to use negative feedback, so we also touch up on the principles of negative feedback. Then we go to another variety of MOS transistor known as PMOS transistor and try to make circuits using PMOS transistor. And we will also look at another technology of making transistors which is the bipolar technology and these transistors are known as bipolar transistors. We see how to make circuits with them and also understand key differences between bipolar transistors and MOS transistors.

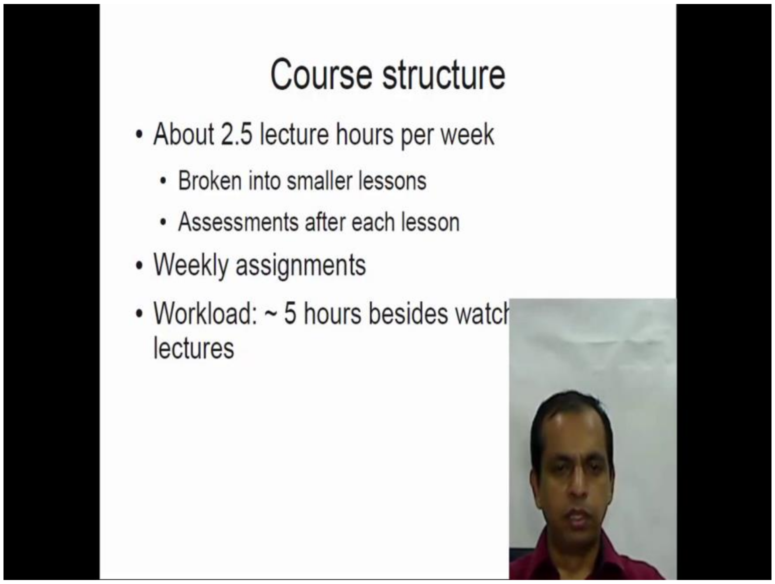
(Refer Slide Time: 09:40)



Week	Unit	Unit contents
1	1	Course introduction; Need for nonlinear circuits; Incremental gain of a two port nonlinear circuit
	2	Constraints on y-parameters and large signal characteristics to obtain a high gain; MOS transistor and its characteristics
2	3	AC coupling network to add signal to bias; AC coupling at input and output; Common source amplifier
	4	Output conductance of a MOS transistor; Inherent gain limitation of a transistor
3	5	Sensitivity of gm to transistor parameters; Biasing a transistor at a constant current; Drain feedback configuration; Current mirror
	6	Common source amplifier using drain feedback
4	7	Common source amplifier using current mirror bias
	8	Common source amplifier using source feedback bias; Using a resistor instead of a current source for biasing; Further biasing techniques
5	9	VCVS using a transistor; Source follower biasing
	10	CCVS using a transistor; CCVS using an opamp
6	11	Biasing a CCVS; Emitter degenrated amplifier
	12	Common gate amplifier and its biasing
7	13	VCCS using a transistor and its biasing
	14	pMOS transistor and its small signal model
8	15	Biasing a pMOS transistor; Converting nMOS circuits to pM
	16	Amplifiers using a pMOS transistor
9	17	Bipolar junction transistor-large and small signal models
	18	BJT circuits- Biasing; Common source amplifier; Emitter foll
10	19	BJT Common base amplifier, Transimpedance amplifier
	20	Swing limits of amplifiers
11	21	Two transistors in feedback
	22	Two transistors in feedback

This is the more detail list that shows you week by week what topics we are going to cover. It is approximately right there may be small changes here and there. And you can of course access this on the course through webpage. I am not going to go through it item by item but the entire course expect will last eleven weeks with includes sort of complete sort of topics that you need to understand this basic of amplifiers, but the first eight weeks will be taken into account for the certification test that is if you want to write a test the test will be based on the first eight weeks but of course you are encourage to go through the last three weeks as well in order to gain the better understanding of the remaining topics.

(Refer Slide Time: 10:23)

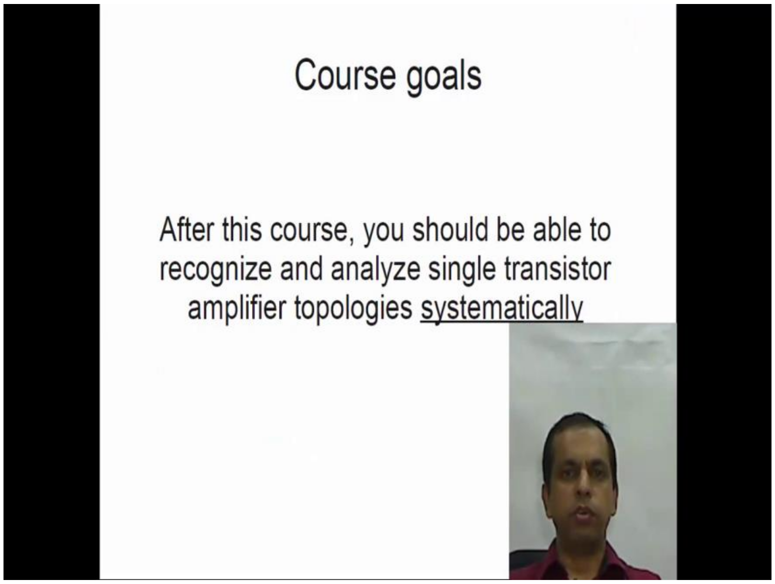


The course structure will be about two and half hours of lectures per week. It will be split up into 2 units usually; and each unit will be split up into smaller lessons usually lasting ten to fifteen minutes. There will be assessments after each lesson and then there will be assignments after each week.And it will due the following weeks. And I expect the workload to be 5 hours besides watching the lectures. This is to be able to understand everything properly and to do the assignments. Of course, it varies very widely between different kinds of students depending on your background and so on.

(Refer Slide Time: 10:59)

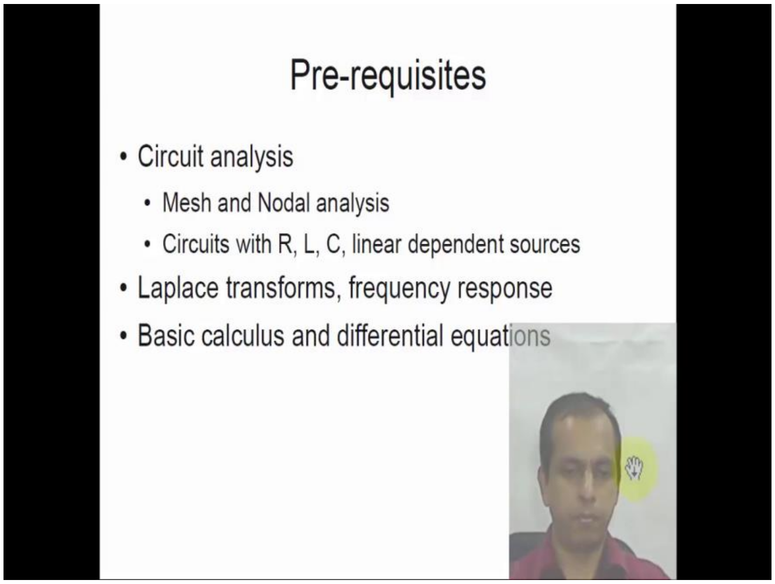
So the course goals are to understand basic amplifiers that is how the basic amplifier topologies come about and so on. Calculations involving amplifiers that is calculation involving what are known as large and small signal conditions, we will see these things later in the course. And one of the things that we try to do in this course is not only tell you that something is on amplifier but try to give you the logic of how the topology came out. And this is very, very important, because even with the single transistor, there is a variety of amplifier topologies; and as the number of transistor increases, the number of topologies simply flow up(11:30). So in order for you to make sense of any complicated circuitry, you have to understand the logic behind the simple building blocks such as single transistors amplifiers. There is no way you can memorize all the circuits and all the results pertaining to them. When you look at any circuit, you have to kind of breaking down into smaller pieces; understand what each pieces doing and also what the entire circuit is doing. Then we'll also look at biasing principles, different ways of setting up of operating points in a transistors and also how to combine variety of biasing arrangements with variety of amplifiers.

(Refer Slide Time: 12:16)



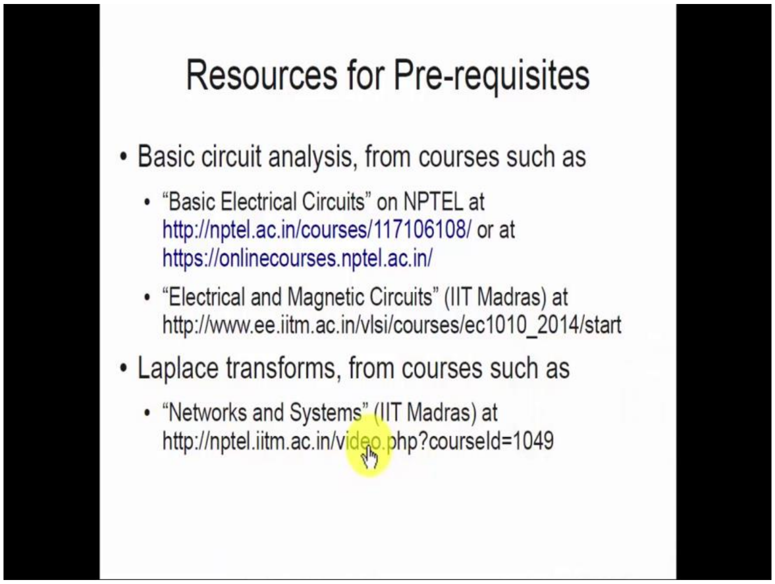
In short, if you learn things well, after this course, you should be able to recognize and analyze any amplifier topology that you see and the keyword here is systematically. I do not mean memorizing some formulas somewhere and somehow getting the right answer, you have to be able to understand the logic behind the circuit and use whatever approximations are necessary and come to the correct answer. Now one of the things that is important to in a course like this, and in general in any advanced course and any field is the important of approximations. The exact formula so complicated that even if you find them and plug all the numbers and get the exact answer, you would not get any insight to the mechanism behind whatever it is that you're analyzing. So, we will frequently use approximations but please understand that approximations are not the same as sloppy calculations. So, in fact they're more difficult than doing the calculation exactly because some approximations are good only in some contexts, so you have to understand the context, understand which approximation is appropriate for it and use it properly.

(Refer Slide Time: 13:21)



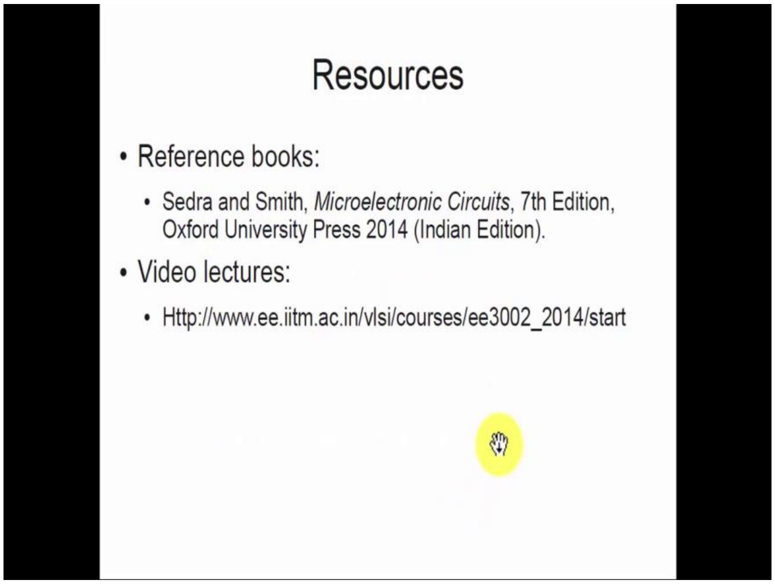
Now in order to go through this course, you need to know certain things, one of course is circuit analysis. You have to know how to analyze any circuit that is any linear circuit containing R, L, and C; this is something that you would have learned in courses such as basic electrical circuits and there are number of references that I have listed if you feel a little rusty about these topics, you can go back to them and refresh your knowledge. And you also need to know Laplace transforms, we would not be use them extensively but we do need them for understanding certain things and of course you need to know basic calculus and differential equations and so on.

(Refer Slide Time: 13:56)



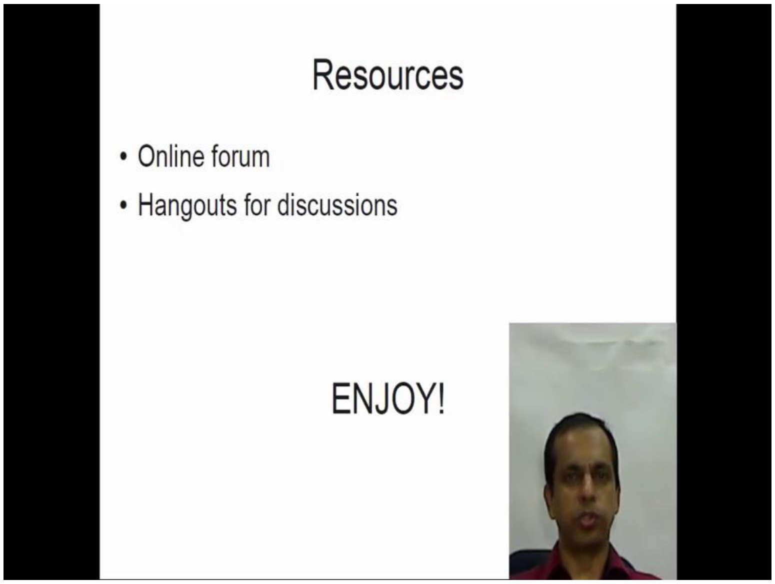
And here are some resources if you want to brush up your pre-requisites. There is NPTEL course on Basic Electrical Circuits that is available at this url, and there is also the Electrical and Magnetic Circuits, both of these are for basic circuit analysis. And for Laplace transform, there are NPTEL courses like Networks and Systems available at this url.

(Refer Slide Time: 14:19)



And for this course, you can refer to this book, we would not be following this exactly, but you can find a lot of material in there. And you can also find video lectures from our group at IIT Madras available at this url.

(Refer Slide Time: 14:34)



And of course, during the course, the online forum is very helpful. You can discuss things with me or the teaching assistance or with other students. And also we will have regularly Schedule hangouts for discussions, may be two or three times to the course; you can use that as well as a live discussion medium. Enjoy the course.